Dark Sector Searches

LAr1-ND Collaboration Meeting
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In This Talk

- Motivate a signature based search for dark sector phenomena in LAr1-ND

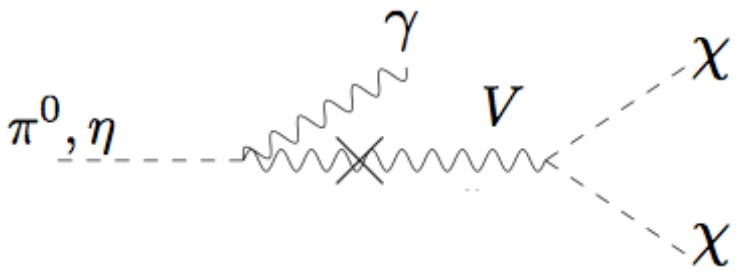
- LArTPC technology allows us to search for topology signatures in a “quasi”-model independent way

- Significant flux impinged on a short baseline detector provides improved sensitivity

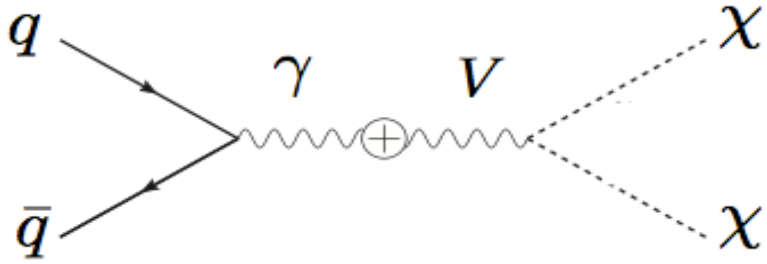
Leptophobic Dark Matter

- Vector boson is a mediator between dark sector and SM that couples dominantly to quarks
- Production of vector bosons through:
  - Production of secondary hadrons followed by decay

  (e.g. pseudoscalar meson decay, scalar meson-vector boson mixing)



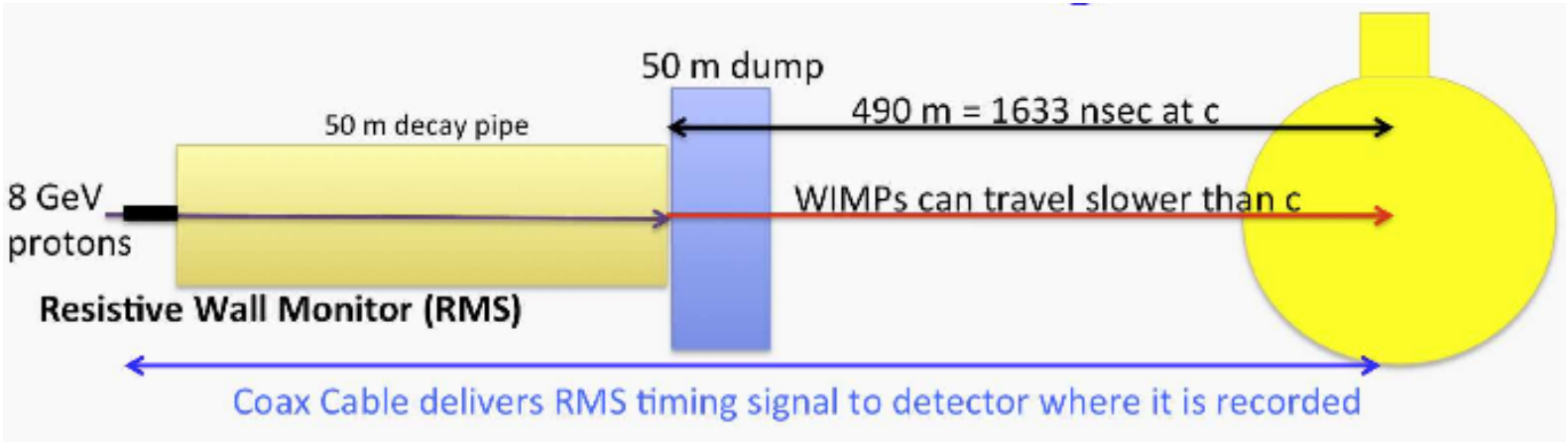
  - Direct QCD production



B. Batell https://indico.bnl.gov/getFile.py/access?contribId=8&sessionId=3&resId=0&materialId=slides&confId=699

DM Neutral Current Elastic Scattering at Fixed Target Neutrino Beam Experiments

MiniBooNE beam dump search



http://www.fnal.gov/directorate/program_planning/Jan2014PACPublic/MB_Request_2013_v2.pdf

$$\pi^0, \eta \longrightarrow V_B \gamma \longrightarrow \chi \bar{\chi} \gamma$$

Vector Boson Visible Decay

If $2m_\chi < m_{V_B}$

$V_B \to \chi\bar{\chi}$

If $2m_\chi > m_{V_B}$

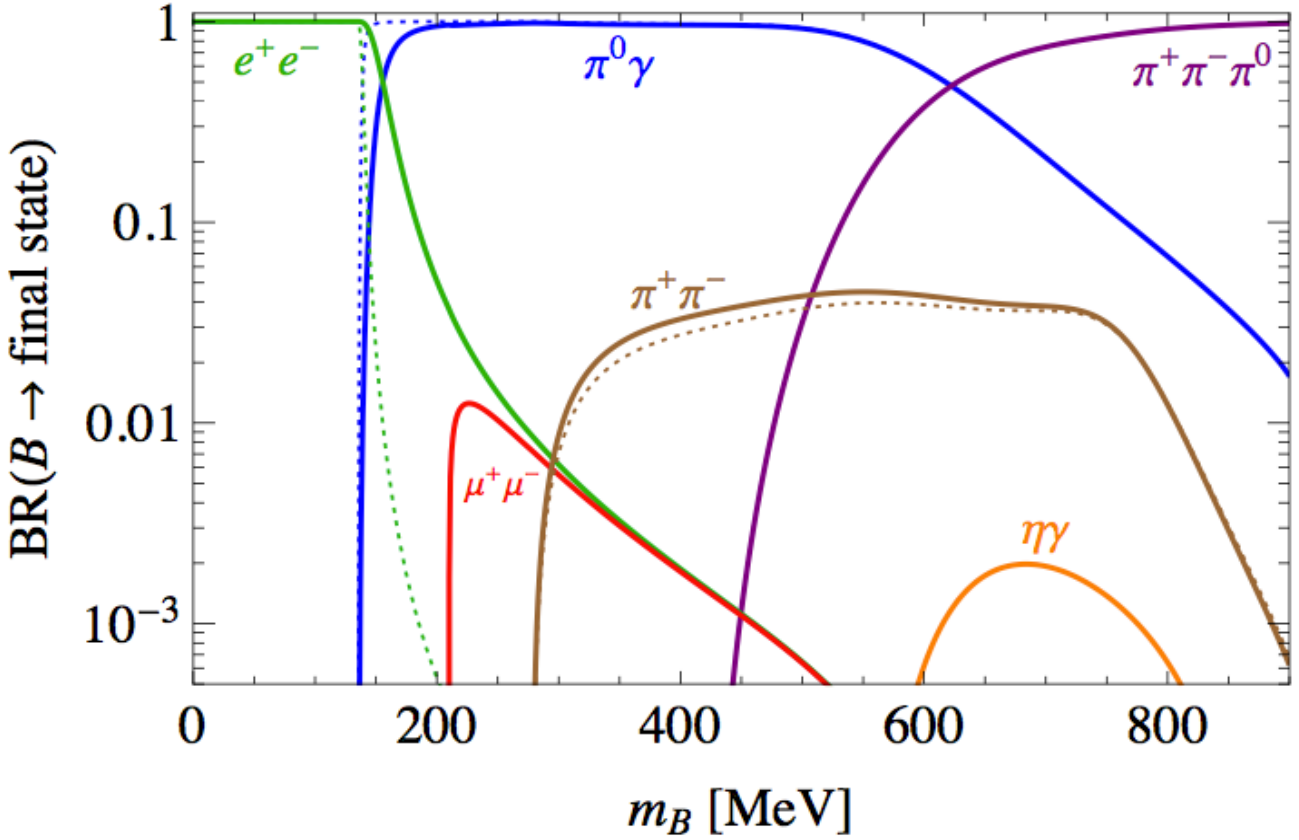
- For $m_{V_B} < m_{\pi^0}$

$V_B \to \pi^0 + \gamma \to 3\gamma$

$V_B \to e^+e^-$

- For $m_{V_B} > m_{\pi^0}$

$V_B \to \pi^0 + \gamma \to 3\gamma$



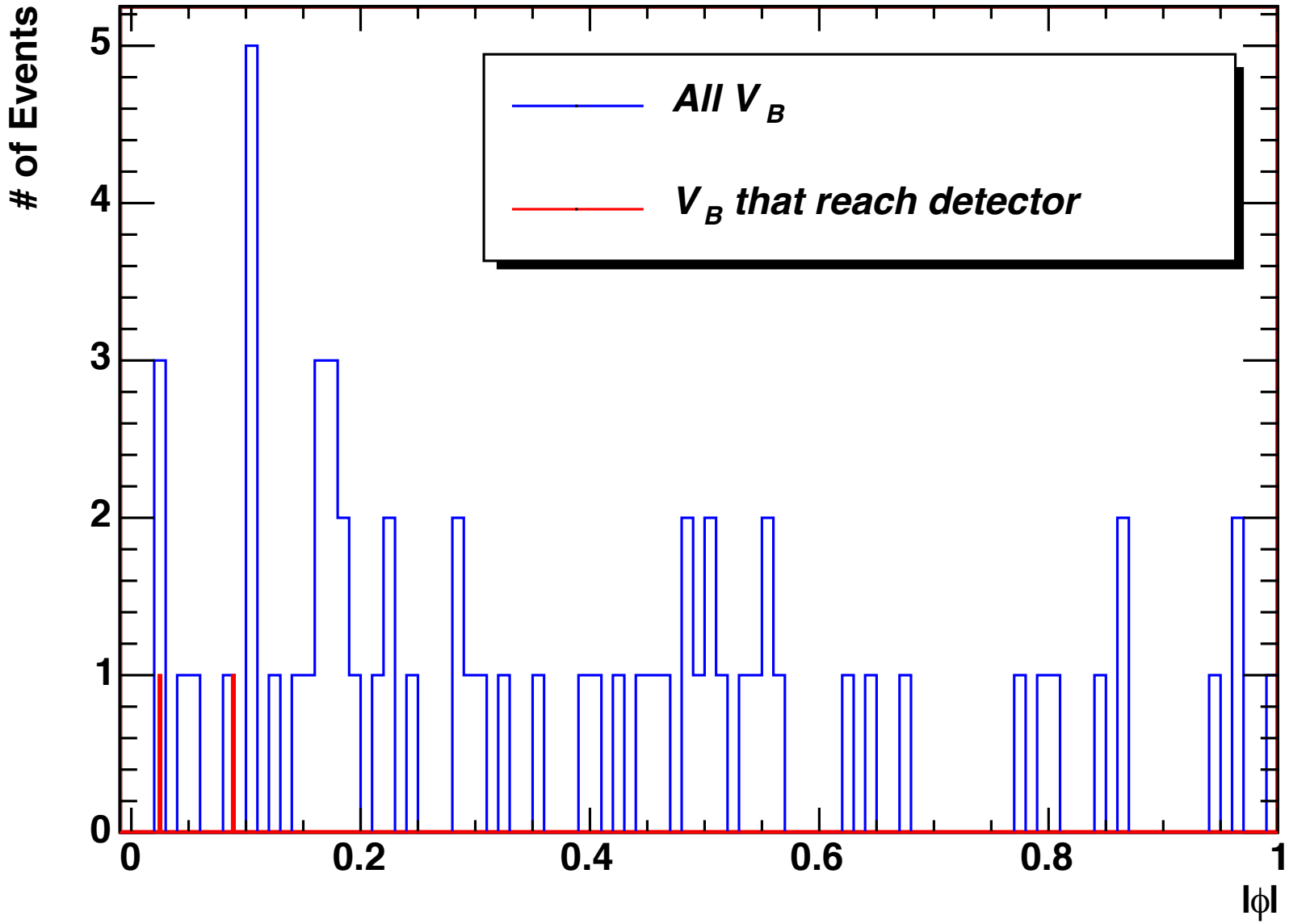
S. Tulin arXiv:1404:4370

Preliminary Monte Carlo Analysis

Objective: simulate vector boson production distributions in LAr1-ND

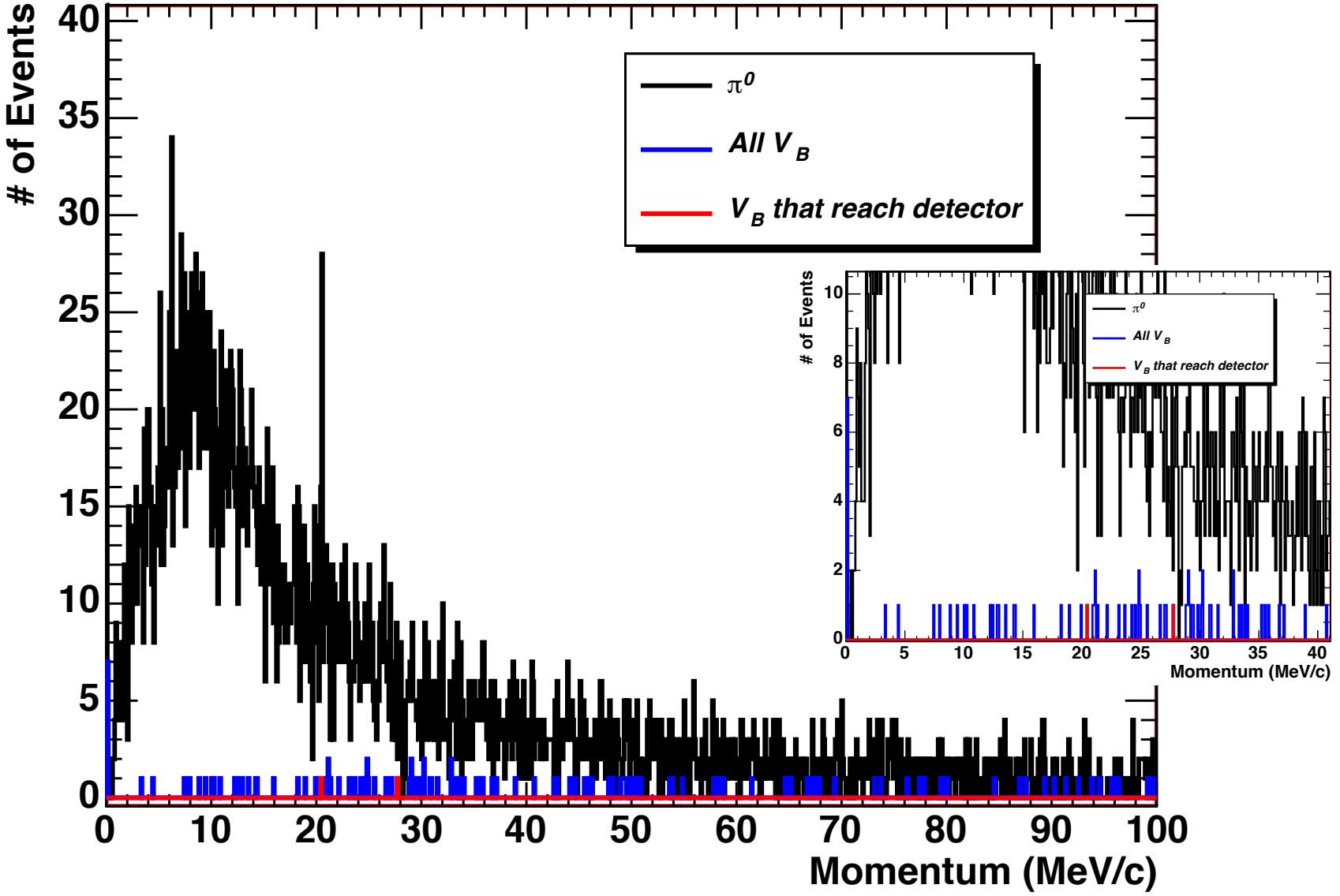
- Using MiniBooNE BNB MC, momentum and angular distribution of π^0s produced in p-Be target interactions were simulated
- Using estimates of the production cross sections , π^0s were selectively replaced with vector bosons
- Vector boson event rate comprises vector bosons possessing trajectories that intercept the LAr1-ND detector

Vector Boson Distribution Angles



*For 2.5×10^{15} POT, m_{V_B} = 500 MeV, in MicroBooNE

Momentum Distribution

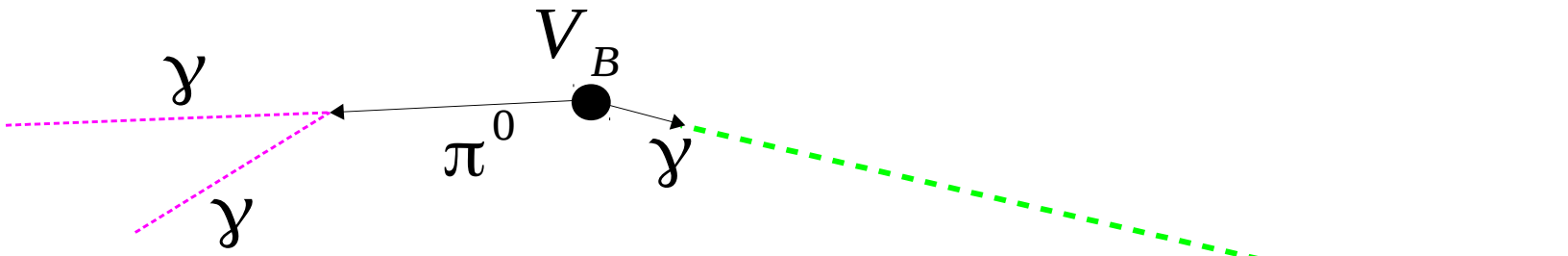


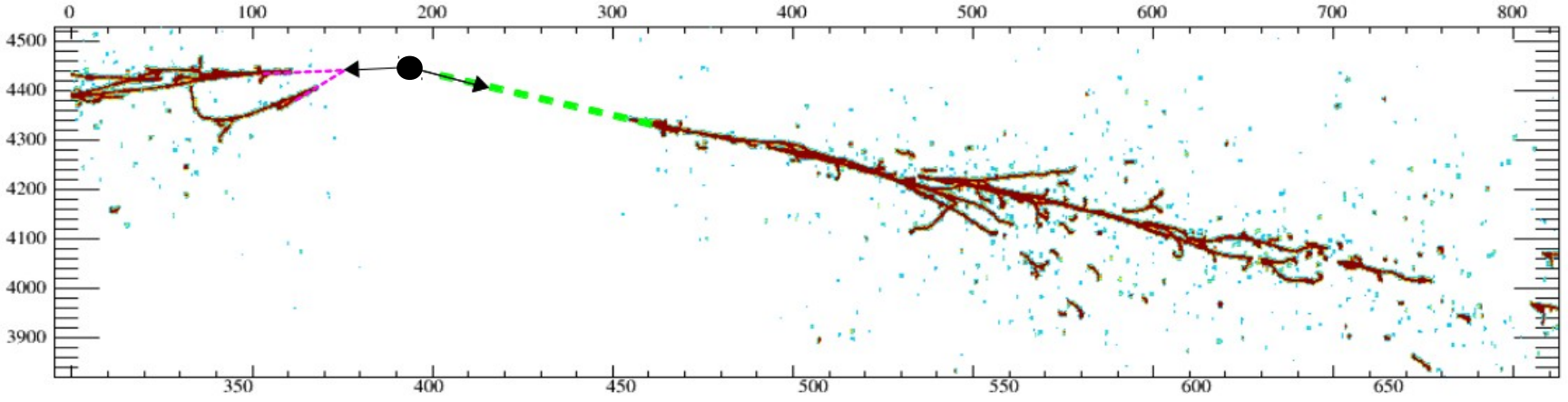
*For 2.5×10^{15} POT, m_{V_B} = 500 MeV, in MicroBooNE

Expected Signature in LAr1-ND

$$V_B \rightarrow \pi^0 + \gamma$$
$$\pi^0 \rightarrow \gamma + \gamma$$

Topology: 3 photons, which we can trace back to a common point with no vertex activity (no hadronic interaction)





Background Analysis: Overview

- Study the three-photon channel in existing MCTruth

- Goals:
  - Identify the types of processes that fake signal
  - Quantify their rate
  - Characterize their kinematics

- Approach:
  - Preliminary spatial cut
  - Geometric / topological search
  - Investigate any differences in beam and cosmic sources
  - Cut based on photon energy and physical distribution

Process Identification

Table 1: Potential Backgrounds (after spatial cut)

Neutrino Source	Booster Beam	Cosmic
Total Number of Events	8200	4600
Total Number of Events with ≥ 3 Photons	6624	3121

Table 2: Characterization of Beam Events with ≥ 3 Photons

Event Type	Number of Events	As a Percentage of ≥ 3 Photon Events
Nuclear Scattering	5491	83%
Neutral Pion Decay	1085	16%
Primary Photon(s)	18	< 1%
Other	30	< 1%

Table 3: Characterization of Cosmic Events with ≥ 3 Photons

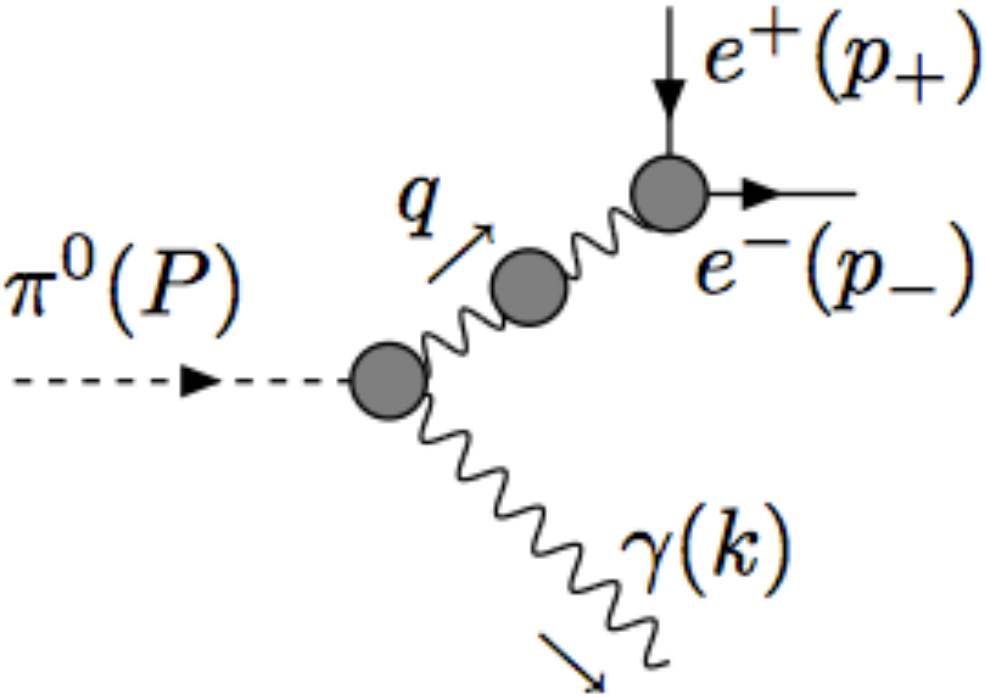
Event Type	Number of Events	As a Percentage of ≥ 3 Photon Events
Nuclear Scattering	2533	81%
Neutral Pion Decay	60	2%
Primary Photon(s)	188	6%
Other	340	11%

Dalitz Decay

- Decay mode:
  ≈1.198 ± 0.032%

- Leading order contribution to amplitude given by electron-positron pair produced by a single photon (Dalitz pair)

- Necessitates further analysis of vector boson kinematics



Next Steps

- Continued development of MC signal/ background
- Expand search to additional signal channels
- Event reconstruction
- Reporting progress in LAr1-ND analysis group